Rockwell Automation

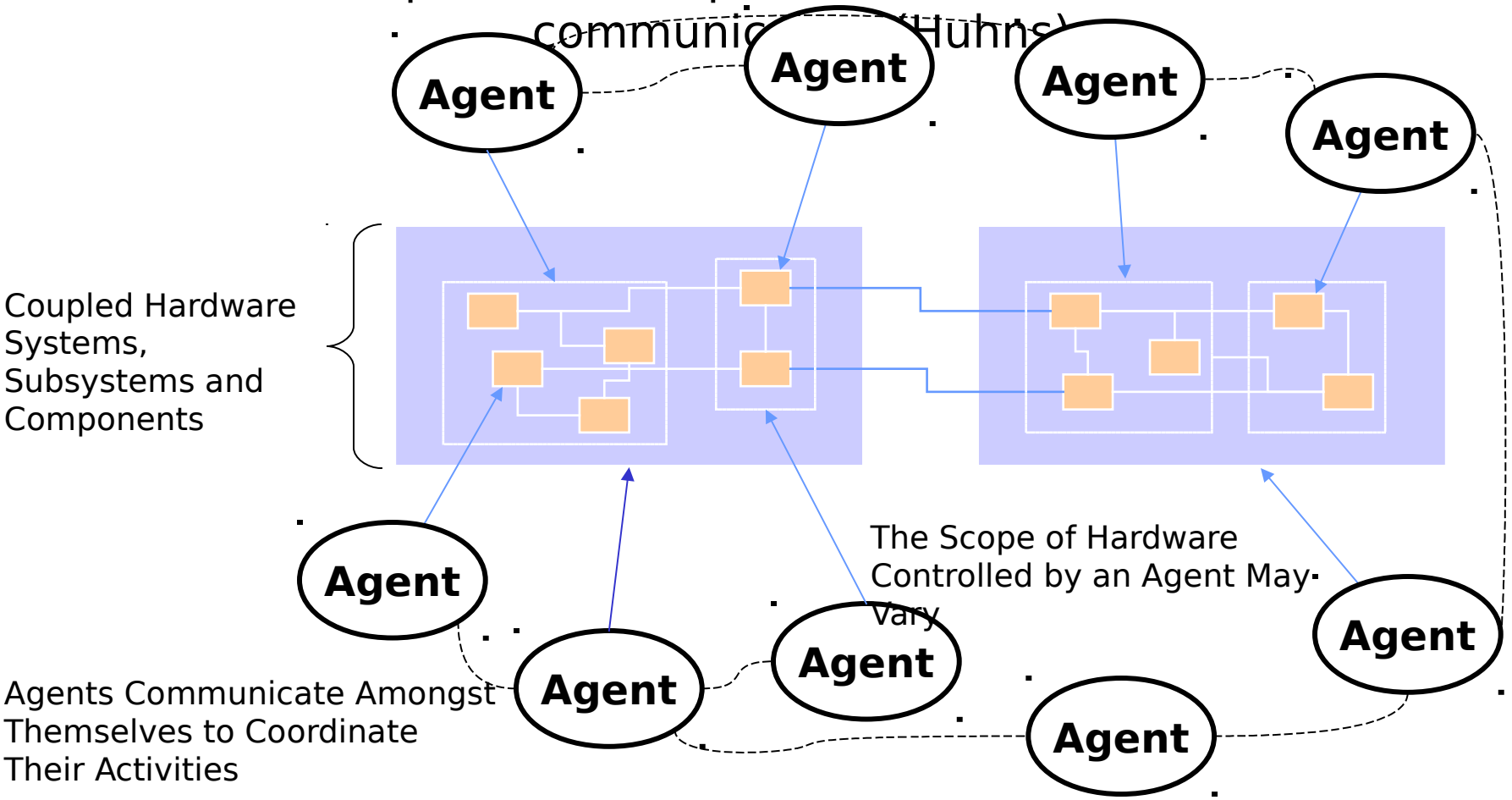
Intelligent Agents

Workshop on Distributed Intelligence for Automated Survivability

Rockwell Automation,
Johns Hopkins University Applied Physics Laboratory

Intelligent Agents

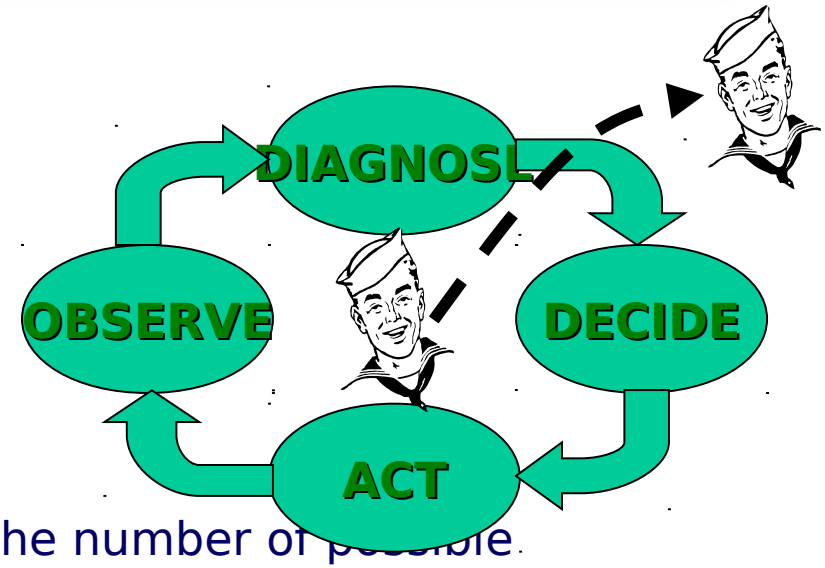
"Agents are active, persistent (software) components that perceive, reason, act, and communicate" (Huhns)



Agents – Core Components of Distributed Control

Agent Advantages

- Intelligent Agents Properties
  - Autonomous -> Reduced manning
  - Cooperative -> Interoperability
  - Self organizing -> Survivability



- Very useful in applications where the number of possible configurations of the equipment is impractically large – too large to accommodate them in traditional programming
  - US Navy ships with redundant supplies and water paths in their chilled water and power distribution systems
  - Large potential for a variety of failures
  - Maximum uptime and survivability
  - Reduced manning

Agent Tasking

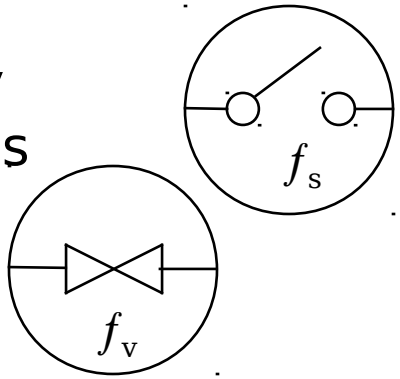
- Diagnosis – Identifying the Current State of the Ship
  Difficult Because:
  - Ship Systems Are Intractably Complex
  - Diagnosis is Complicated by the Probability of Multiple Simultaneous Failures Resulting From Battle Damage
  - Sensors, being subject to battle damage, cannot be relied upon

- Resource Allocation – Configuring the Ship Systems
  - Efficient Usage of Limited Resources is Desired
  - Maintaining Ship Readiness is Required

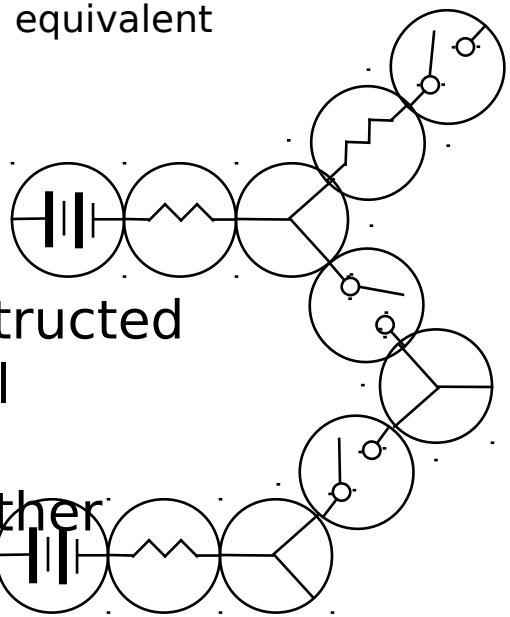
  This is Difficult Because:
  - Ship Systems Are Intractably Complex
  - Interdependencies Between Subsystems Limits Decomposition

Previous Work: Model-based Reasoning Agents

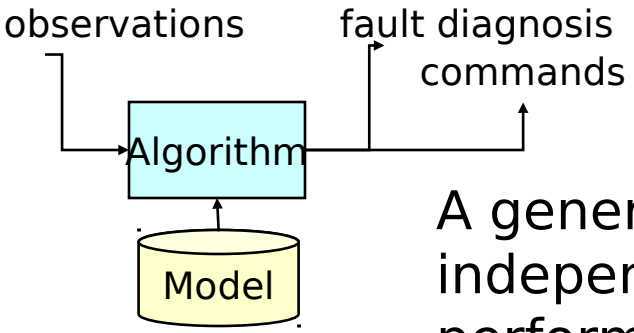
Each component is modeled by a set of mathematical equations that represent how that component effects its external interfaces



Component models are reusable, e.g. AMP RDIP Hex switches are all equivalent



System Models are constructed by mirroring the physical system by constraining component models together

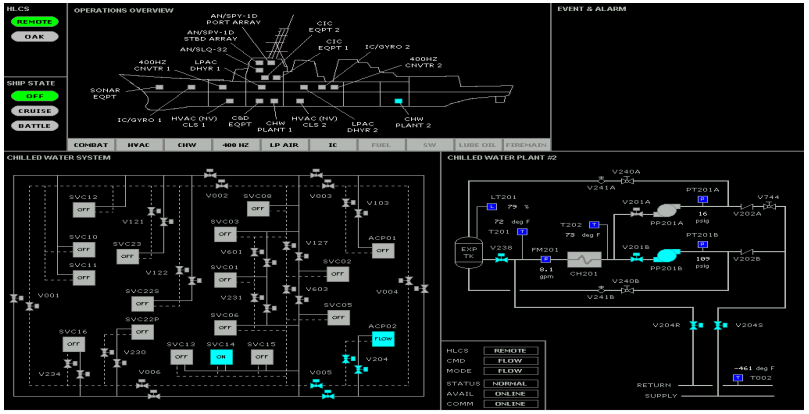


A general, application independent algorithm is performed diagnosis, safing and reconfiguration

Previous Work: Model-based Reasoning Agents

Model-based Agent control was demonstrated on the NSWC Chilled Water System Reduced Scale Advanced Demonstrator throughout FY02 and FY03. These demonstrations showed:

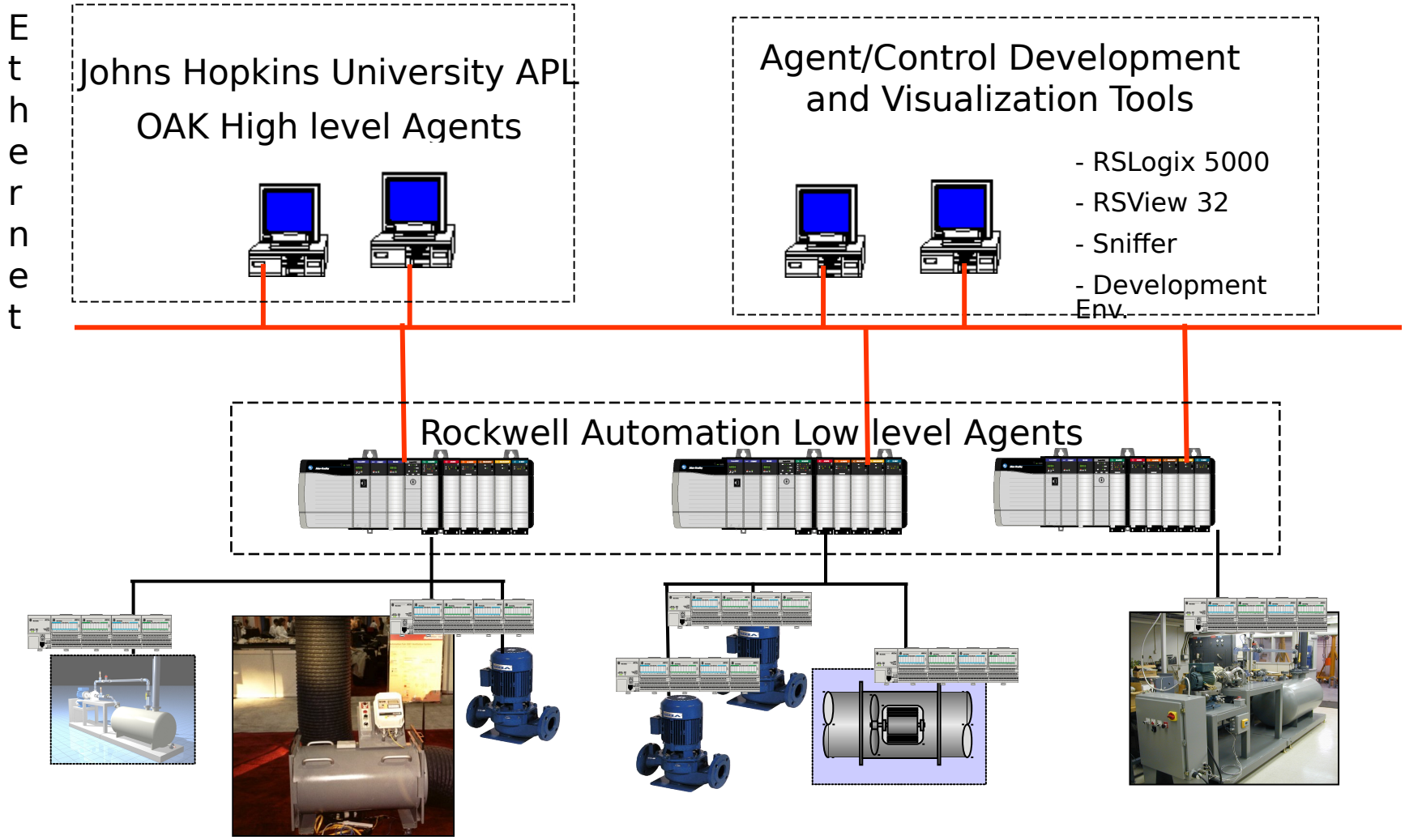
- The ability to diagnose failures, including multiple simultaneous failures, without the need for internal sensors
- Responding to failures with adaptive reconfiguration not through pre-ordained reactions
- Reconfiguration based upon current ship needs (e.g. battle stations)
- Distributed Control
- Communication of inferred failures and reconfiguration actions of human operations
- Responsiveness to Operator provided requirements without the dependency upon human attention or action.



Ongoing Work

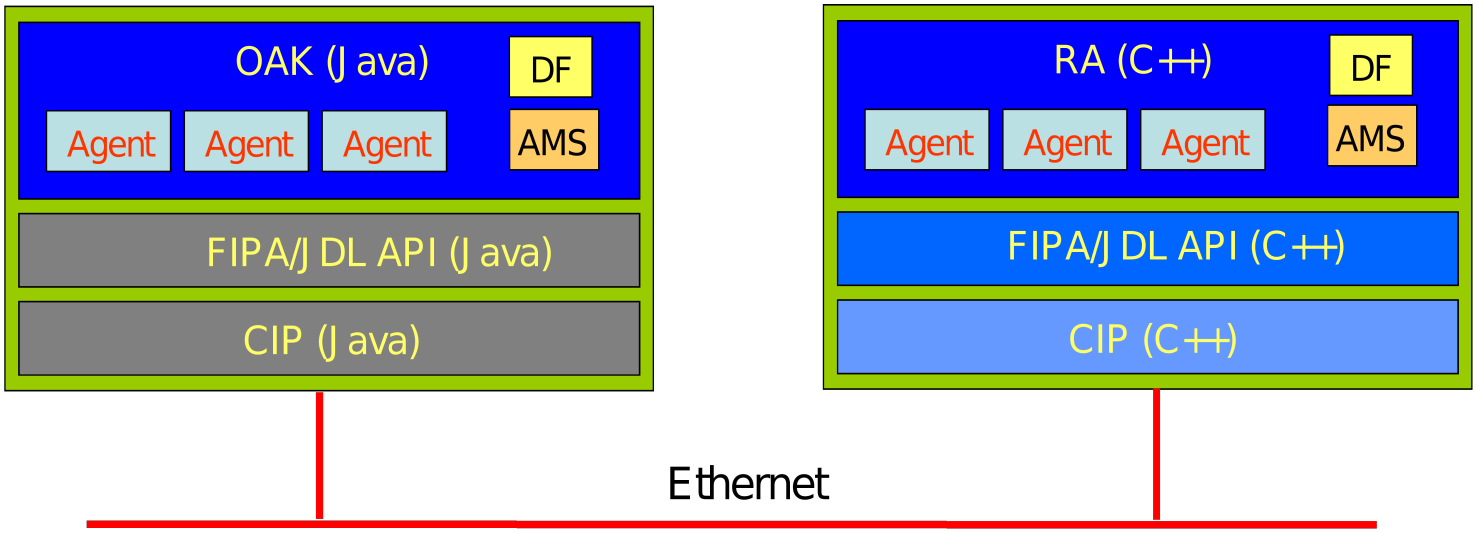
- Integration of Multi-Agent Systems
- Improved Reasoning
  - Active Diagnosis
  - Hybrid Model
- Multi-System Coordination

Integration of Multi-Age Systems using COTS



Software Architectur

- Combined RA/JHUAPL agent systems
  - Implement a communication interface and API based on CIP, JDL and FIPA languages to connect the agents



Design and Validation Using Simulation

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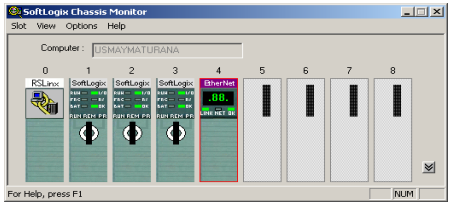
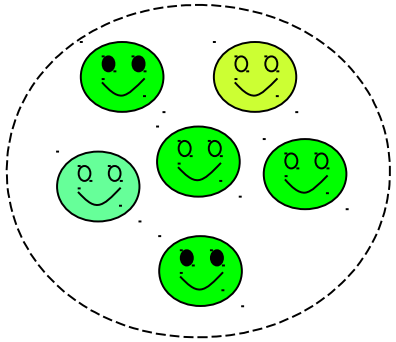
Soft controller

Contained

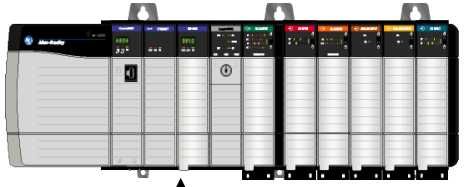




Agent organization

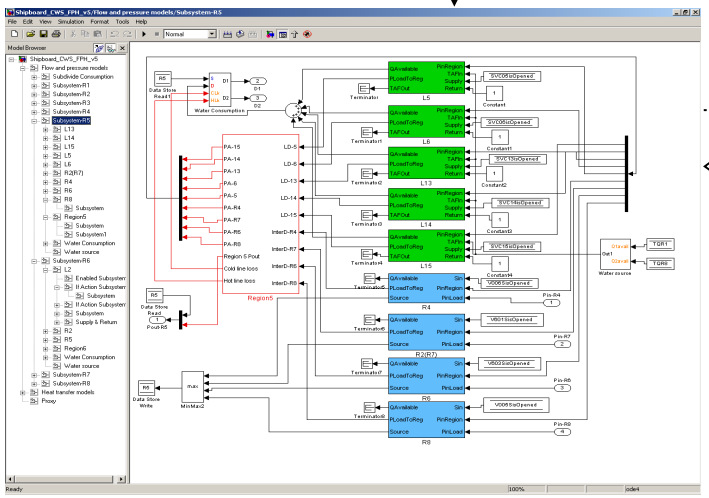
Contained

Hardware controller



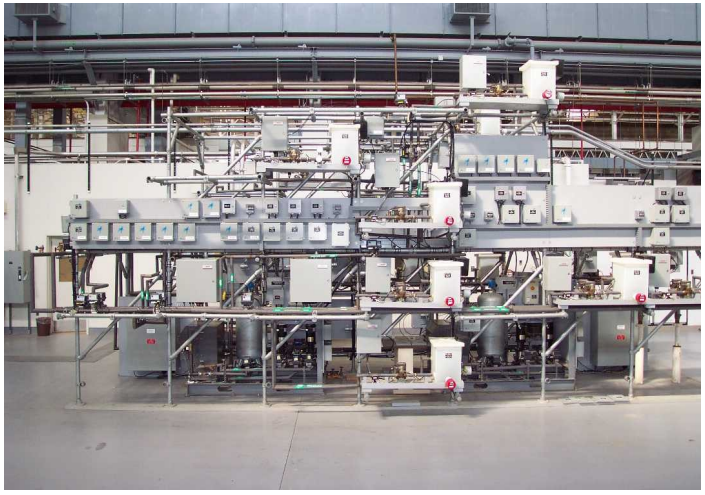
Common Inputs/Outputs Interface

Simulink Simulation



Software Equivalence

Carderock



High and Low Level Agents for the CWS

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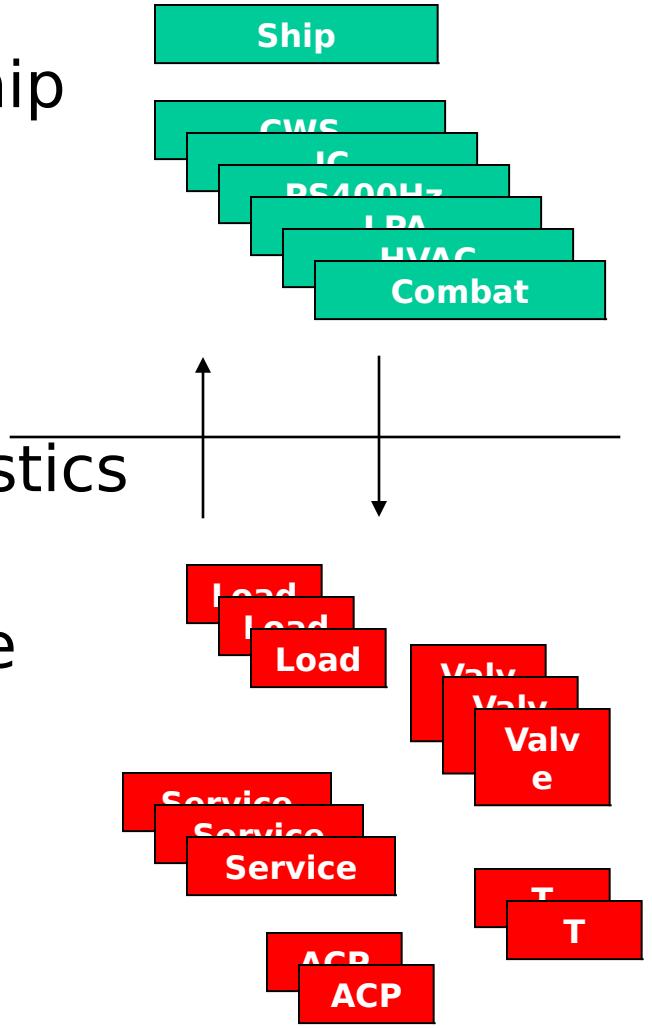
JHUAPL Agents

- Understand ship's modes
- Understand interactions of ship systems
- Change load priorities
- Change capacity limits for supplies
- Perform model-based diagnostics

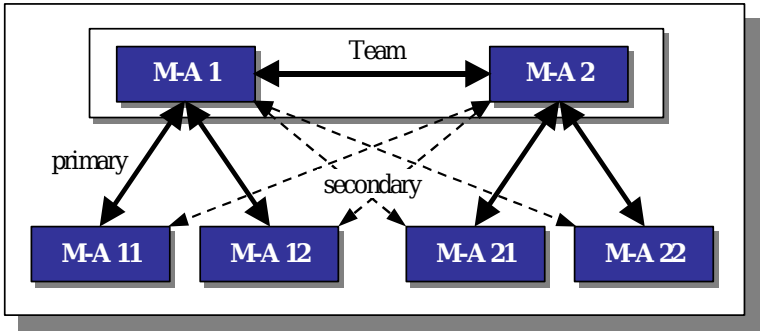
RA Agents

- Control the CWS equipment
- Use the chilled water resource efficiently
- Reconfigure water paths
- Perform basic equipment diagnostics
- Perform active diagnostics to



Directory Facilitators

Controllers are initialized with Local and/or Global Directory Facilitators which are a type of Middle-Agents (MAs)



- **Knowledge Propagation Techniques**
  - **Full propagation**
  - **No propagation**
  - **Partial propagation**

Informs GDF about new Agents

Global DF

Informs other DFs about new Agents

Local DF

Registration of agent capabilities

Remote systems

Local DF

Local DF

Agent

Agent

Agent

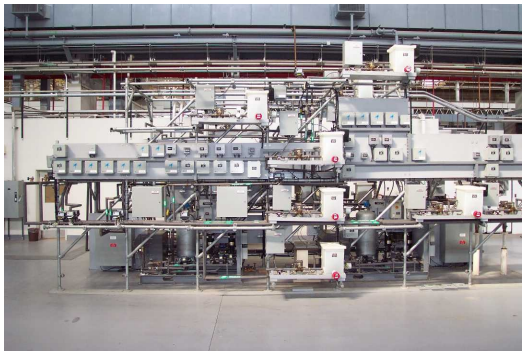
Agent

Agent

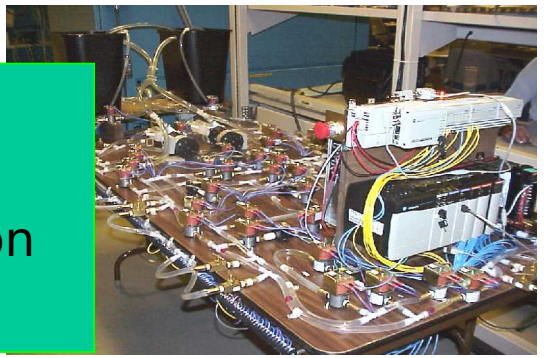
Agent

Implementation

NSWC



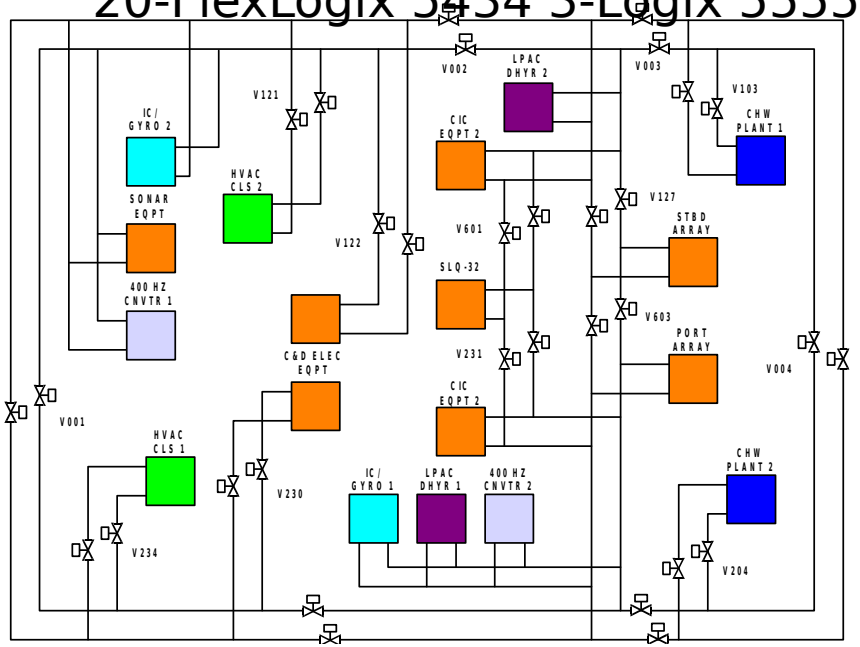
Matlab Simulation



Tabletop

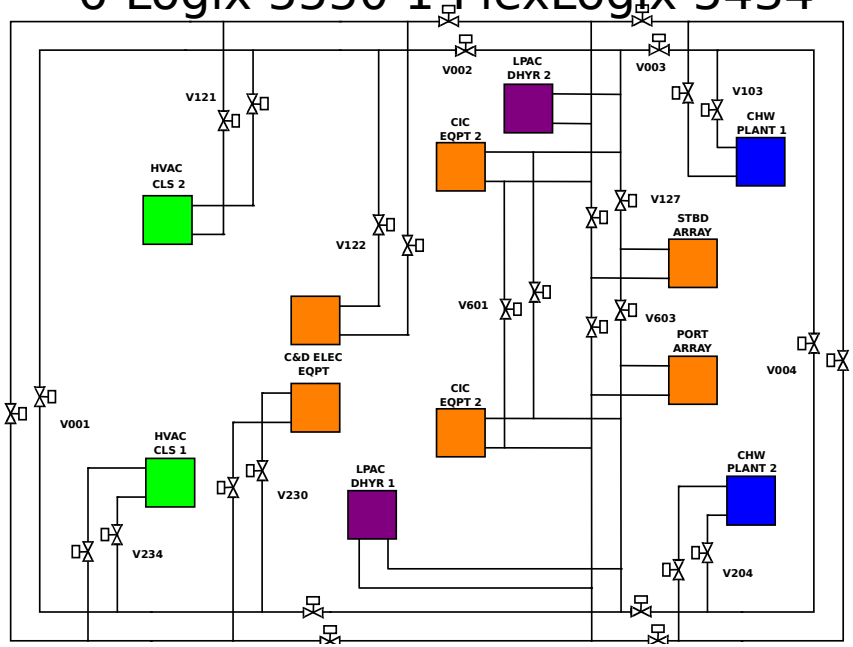
Total # of agents: 68

20-FlexLogix 5434 3-Logix 5555



Total # of agents: 52

6-Logix 5550 1-FlexLogix 5434



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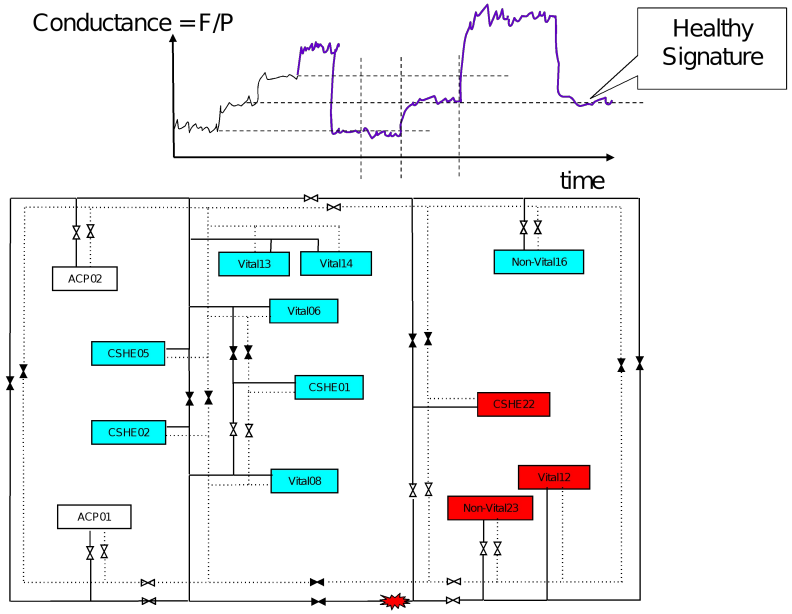
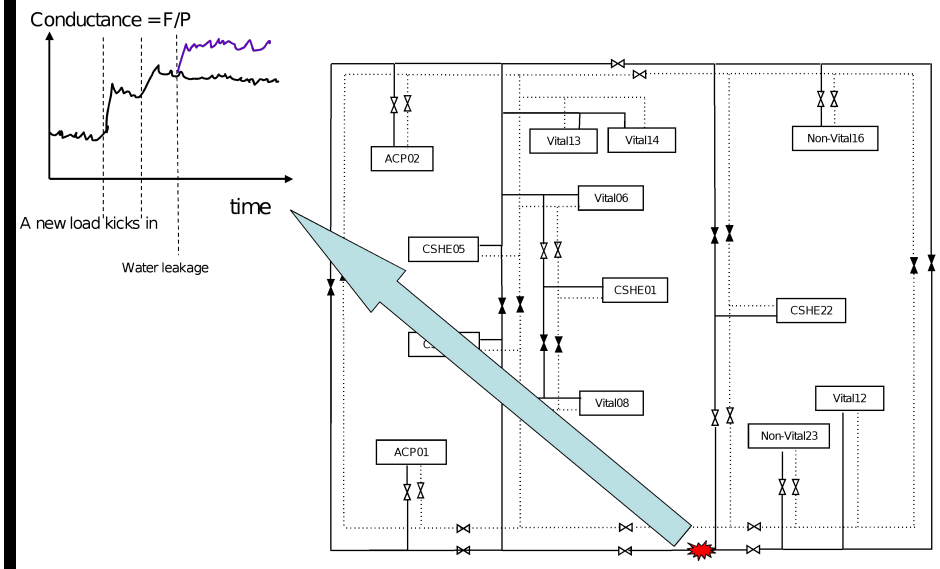
Improved Reasoning: Active Diagnostics System

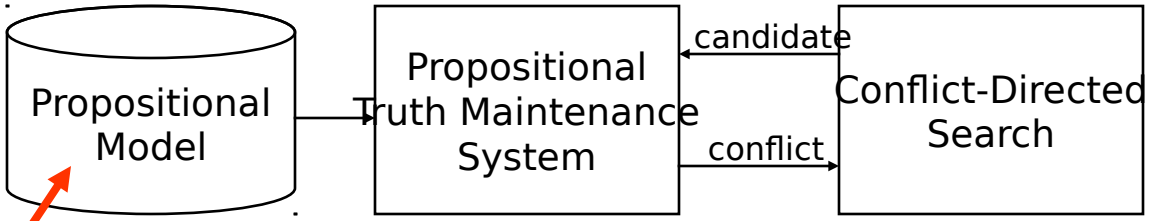
- Passive Detection
  - Agents use conductance *(R = Flow/Pressure)* to detect leakages
- Agents collaborate to detect the actual location of the leakage
  - Agents observe the variations in the conductance signature under controlled piping configurations
  - Upon final detection, the Agents isolate the damage and reconfigure the piping system



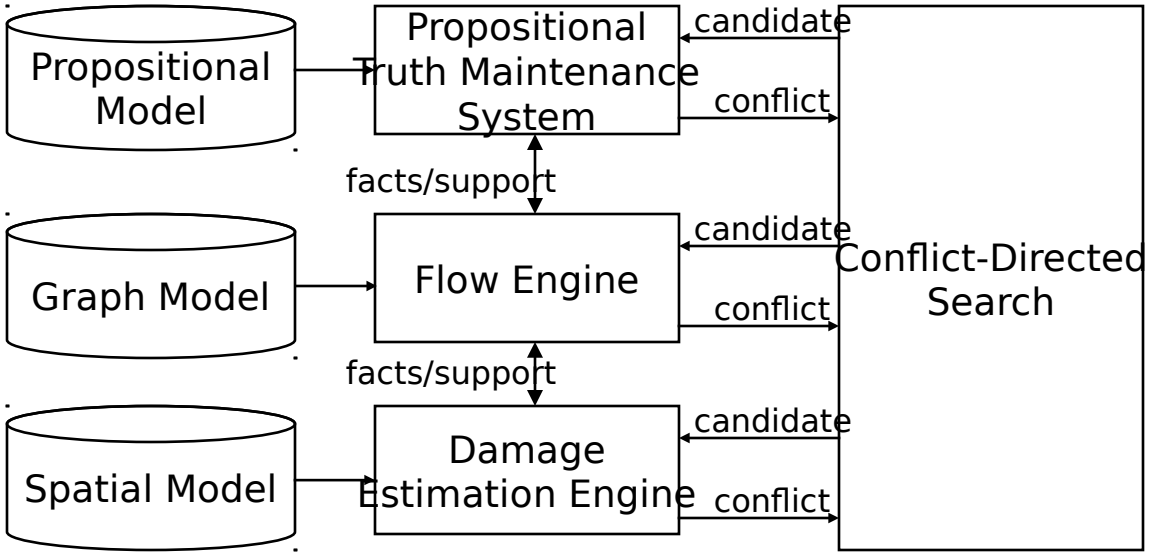


Improved Reasoning: Hybrid Models

Current Reasoning Engine



Insufficient to Model Many Real-World Faults



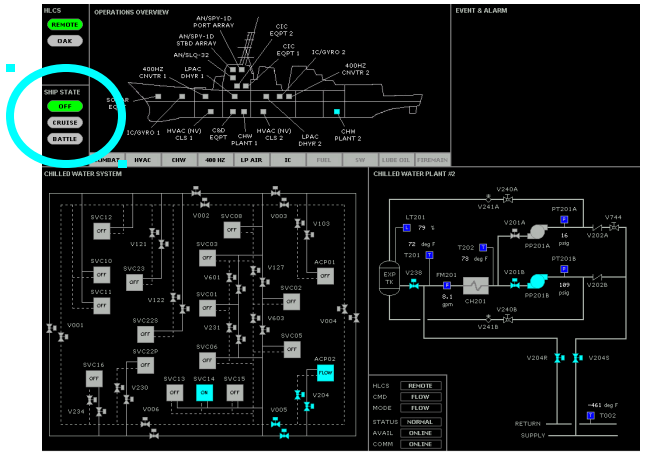
New Reasoning Engine

Effects Modeling

Original Ship States

- Off: {CIC, off; SLC32, off; …}
- Cruise: {CIC, on; Sonar, on; …}
- Battle: {CIC, on; Sonar, on; …}

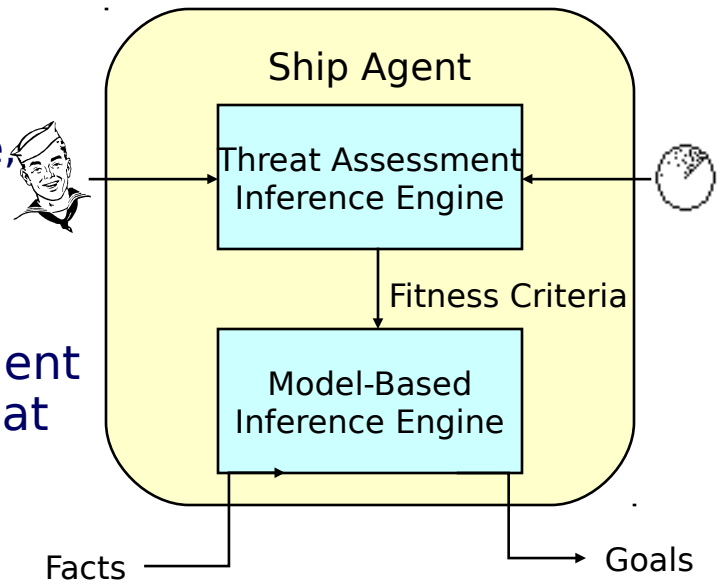
has become…



Ship Operational Parameters:

- Ship Readiness: {Maximum, Moderate, Minimum}
- Threat Type: {Active Air, Passive Air, Surface, …}
- Spatial Risk Area: e.g. aft port quarter

These parameters are used by the Ship Agent to define current operational needs (what loads require resources) and the fitness criteria for the auxiliary systems

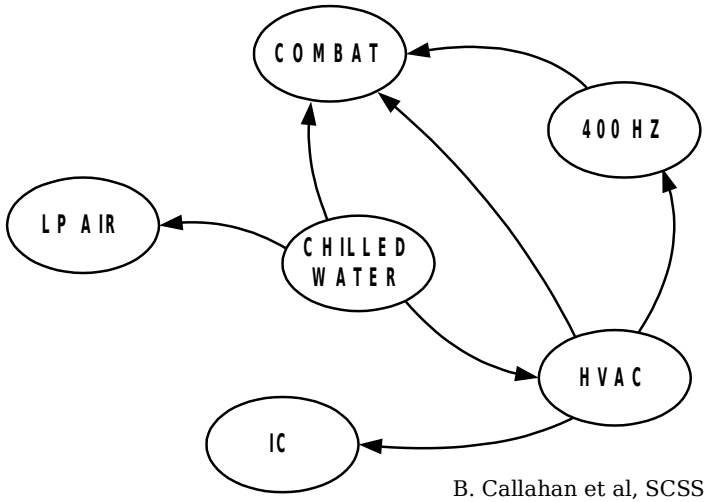


Multi-System Coordination

Ship Systems Are Interdependent

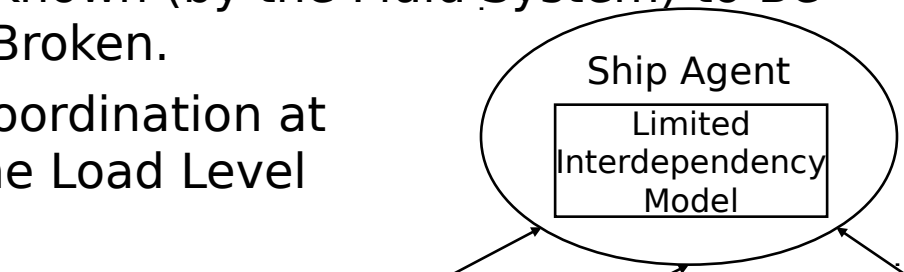
Knowledge of the State of One Subsystem Is Necessary For Optimal Control of Another Subsystem; otherwise…

A Ship's Electrical System May Supply Electrical Power to a Pump that is ~~Known (by the Fluid System) to Be~~ Broken.

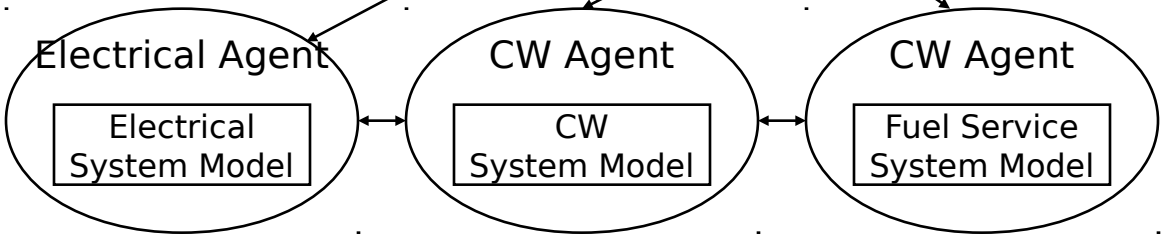


B. Callahan et al, SCSS 2002 paper

Coordination at the Load Level



e.g. If a load cannot be "on" due to failures, set it, and it's supplies "off"



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Coordination at the System Level

Inter-system dependencies are modeled, yet inferencing is limited and subordinate

Acknowledgements

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N00014-02-C-0526

- Thanks to Syntek for support in understanding Ship Construction, Operations and Doctrine.
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- Thanks to Fairmont Automation for their support in RSAD integration